HERBICIDE RESIDUE IN SURFACE WATER FOLLOWING AND APPLICATION OF ROUNDUP® IN THE REVELSTOKE FOREST DISTRICT

by
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1 INTRODUCTION

The use of herbicides to reduce weed competition in the establishment of forest stands is increasing in British Columbia (Henigman 1986). A common concern about the use of herbicides is their effect on water quality. To address this concern, a program was undertaken in the Revelstoke area to monitor herbicide residues in surface water draining a cutblock on which Roundup® was operationally applied.

Roundup®, whose active ingredient is glyphosate (N-[phosphonomethyl] glycine), is relatively new to operational forestry applications. Originally it was introduced by Baird *et al.* (1971) for use in agriculture. Glyphosate is a broad spectrum, relatively non-selective herbicide that effectively controls most annual and biennial herbaceous plants and some deep rooted perennial species (Weed Science Society of America 1979). Application is made as a post-emergence spray to the target vegetation. Uptake is through the foliage, from where the herbicide is translocated through the plant. Studies related to glyphosate have been compiled by Chykaliuk *et al.* (1981). As well, the U.S. Department of Agriculture Forest Service (1984) prepared a detailed information review on the toxicology, environmental fate, and hazard assessment of glyphosate.

Norris *et al.* (1983) described several pathways for herbicide residues to enter water: direct application, drift, mobilization in ephemeral stream channels, overland flow, and/or leaching. To minimize the movement of herbicides through these pathways, pesticide use permits in British Columbia require a 10-m pesticide-free zone (PFZ) surrounding all water courses. In addition, current practice involves using a 100-m or wider buffer around water courses where aerial application of herbicide is planned.

Witt has suggested that the measurement of glyphosate residues in surface water indicates off-site movement, and is cause for re-evaluation of the application program.[1] Little information exists in southeastern British Columbia on the movement of glyphosate under local conditions.

The objective of this study was to assess the off-site movement of glyphosate and its metabolite AMPA (amino-methyl-phosphonic acid), following an operational application of Roundup®, by monitoring a surface water source for residues of the herbicide.

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[1] Witt, J. 1986. Using herbicides: impact on water. From a meeting on Vegetation Management Options in Southern Interior Forests. Assoc. of B.C. Professional Foresters/Southern Interior Silv. Committee. Nelson,B.C. Unpubl. paper.

2 METHODS

2.1 Site

The site chosen for the application and monitoring of Roundup® is a 97-ha cutblock in the Kirkup Creek drainage, a tributary of Jordan River, located about 8 km northwest of Revelstoke (Figure 1). Elevations on the cutblock range between 1036-1280 m, with slopes from 15 to 60%. The block lies in the ICHb biogeoclimatic subzone (Utzig *et al.* 1986). The area was clearcut in stages between 1972 and 1976. The majority of the cutblock was broadcast burned in 1973. The unit was planted in 1974 with Engelmann spruce (*Picea engelmannii*) and again in 1980 with Engelmann spruce and western redcedar (*Thuja plicata*). The encroachment of competing vegetation upon the planted seedlings has resulted in the failure of the plantation. The competing vegetation includes *Alnus virides*, *Acer glabrum*, *Epilobium angustifolium*, *Rubus* spp., *Pteridium aquilinum*, and *Salix* spp.

2.2 Soils

The soil on the site is an acidic sandy-skeletal Orthic Humo-Ferric Podzol with a 7.5 cm Mormoder humus layer (Table 1). The majority of the area is well drained except around the emergence of seeps.

TABLE 1. Summary of physical and chemical soil properties[a] from a site within the herbicide-treated cutblock

Horizon	Depth (cm)	Total coarse fragments	Texture	Texture (%)			pH	C.E.C. (meg/100g)	% Carbon (Leco)
				Sand	Silt	Clay			
L	7.5-7.0								
F	7.0-5.0						5.1	103.1	44.2
H	5.0-0.0						4.8	113.8	48.9
Ae	0-3	20	LS	72.9	23.6	3.5	4.2	10.5	1.5
II Bf	3-21	35	SL	68.0	25.8	6.2	4.7	26.5	3.6
III BC_1	21-40	65	S	86.8	10.4	2.8	4.6	7.5	0.8
III BC_2	40-80	65	S[b]						
III C	80-200+	85	S[b]						

Family particle size: Sandy skeletal

Soil type: Orthic Hemo-Ferric Podzol

[a] Analysis of soils carried out by Analytical Laboratory, Research Branch, Ministry of Forests, Victoria, B.C.
[b] Determined by hand texturing.

2.3 Sample Location

Within the treated block, several surface water courses exist. The source selected for monitoring emerges as surface flow at the lower slopes of the treated block (Figure 1). Flow consists of several low-volume seeps emerging along several defined channels. These seeps converge to form a single flow at a lower elevation. The actual point of sampling on this single flow was 170 m below the boundary of the 100-m buffer. Water samples were taken from the surface source as described in Section 2.5. This location was chosen because it was fairly central on the cutblock and application of herbicide was to be carried out immediately above and around the water source. The topography and drainage pattern on the cutblock indicate that most of the source area contributing to the monitored flow lies within the cutblock and was treated with the herbicide.

2.4 Herbicide Treatment

Roundup® was applied on the block by two methods, aerial application and ground application. Aerial

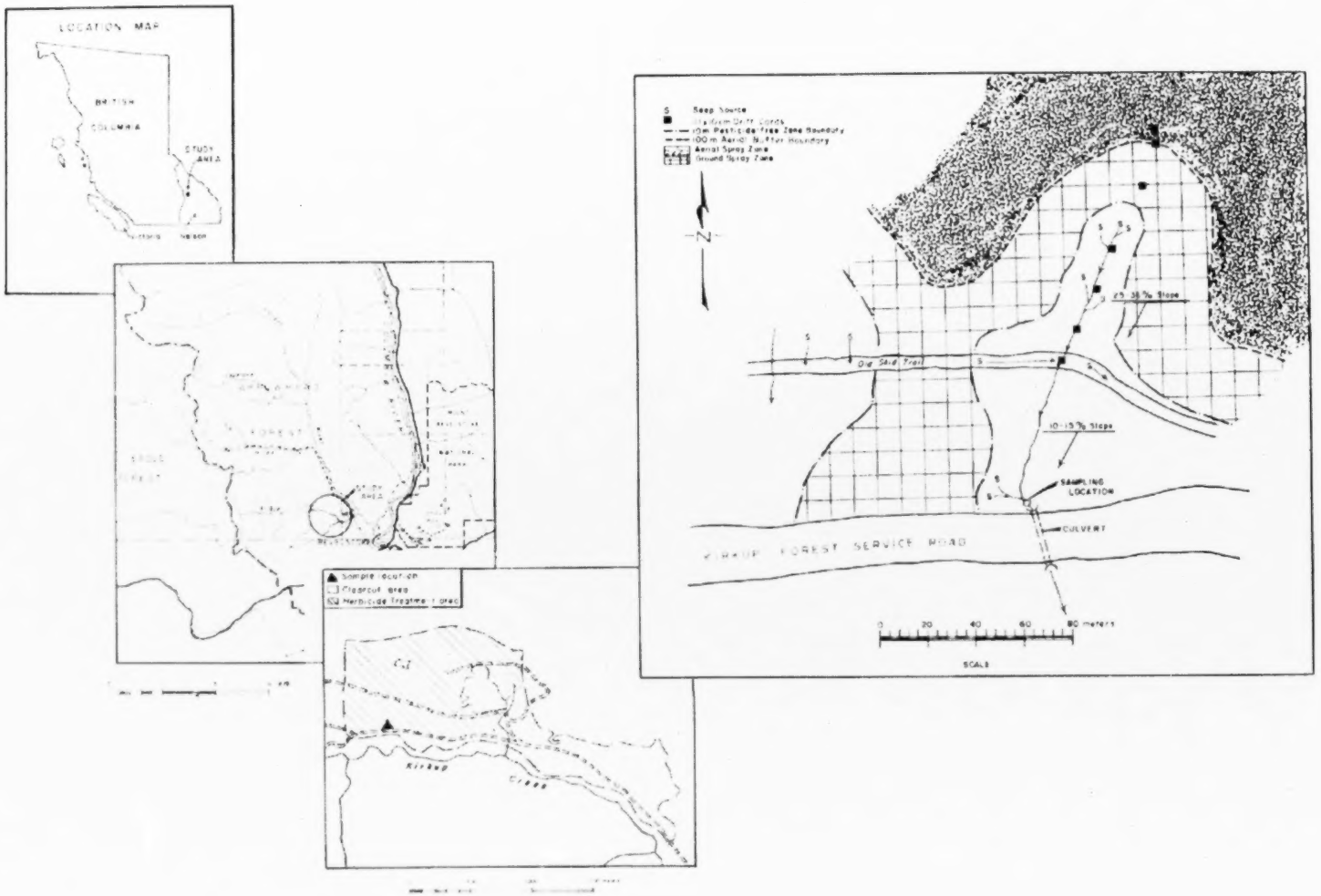

FIGURE 1. Location in southeastern British Columbia of the hervicide-treated cutblock and the water sampling site.

application began at 16:50 P.S.T. on 16 August 1986 and concluded at 19:52 of the same day. Aerial application immediately upslope of the water source occurred at 18:30. Ground application began in the buffer areas at 05:30 on 17 August and concluded at 14:00. The buffer surrounding the monitored spring was sprayed starting at 08:30. Aerial application was in an east-west direction along the contours, whereas ground application was downslope in a southerly direction.

Aerial application was made using a Bell 206 helicopter equipped with a 7.54 m Simplex boom consisting of 52 RD10 nozzles oriented 45° back. Flying height varied from 15 to 20 m at an average speed of 75 km/hr, providing a swath width of approximately 14 m. Application rate was 1.78 kg active ingredient (a.i.)/ha. To document the occurrence of drift and overspray, red dye was added to the mixture so that droplets could be identified on 10 x 10 cm Krome-Kote® drift cards in the study area. Ground application was made by a crew of eight personnel using backpack sprayers. Application rate was 1.40 kg a.i./ha. No dye was used in the ground application mixture.

Of the 97 ha in the block on which Roundup® was applied, 45 ha were done by aerial application, 49.5 ha were done by ground application, and 2.5 ha received no treatment.

2.5 Sampling Procedures

All samples were collected in 1-L polyethelene bottles supplied by the B.C. Ministry of Environment laboratory. Water was collected from 2 to 10 cm depth at mid-stream by the grab method (Ponce 1980). Flow was measured at the outlet of a culvert immediately below the sampling point, using a bucket and stopwatch. It is possible that not all water was measured, as some seepage below the road fill was evident. Measured flows never exceeded 1 L/s during the monitoring period, including periods following rainstorms.

Sampling started on 16 August 1986 with one sample collected immediately before the herbicide was applied. Single samples were collected at 6 minutes, 30 minutes, 1, 2, 4, 6, 12, 15, 16, 18 hours; and 1, 1.5, 2, 3, 4, 5, 6, 8, 14, 16, 22, 28, and 36 days following initial herbicide application above the sample location.

Samples were shipped to Vancouver for analysis by the B.C. Ministry of Environment laboratory. The first 13 samples were shipped on ice; subsequent samples were frozen prior to shipping. Water samples were analysed for glyphosate and AMPA residues by derivatization and High Performance Liquid Chromatography (G. Masson, pers. comm., Ministry of Environment Laboratory). The detection limit for both was 0.005 mg/L with strict quality control measures carried out by the lab.

2.6 Weather

During the aerial spray, wind speed was monitored by a hand-held anemometer and never exceeded the maximum recommended limit of 2.2 m/s during the operation. Daily average air temperature as recorded by the Atmospheric Environment Service at the Revelstoke airport, and daily precipitation recorded on site during the water monitoring period, are presented in Figure 2. The frequency of sampling for herbicide residues is indicated.

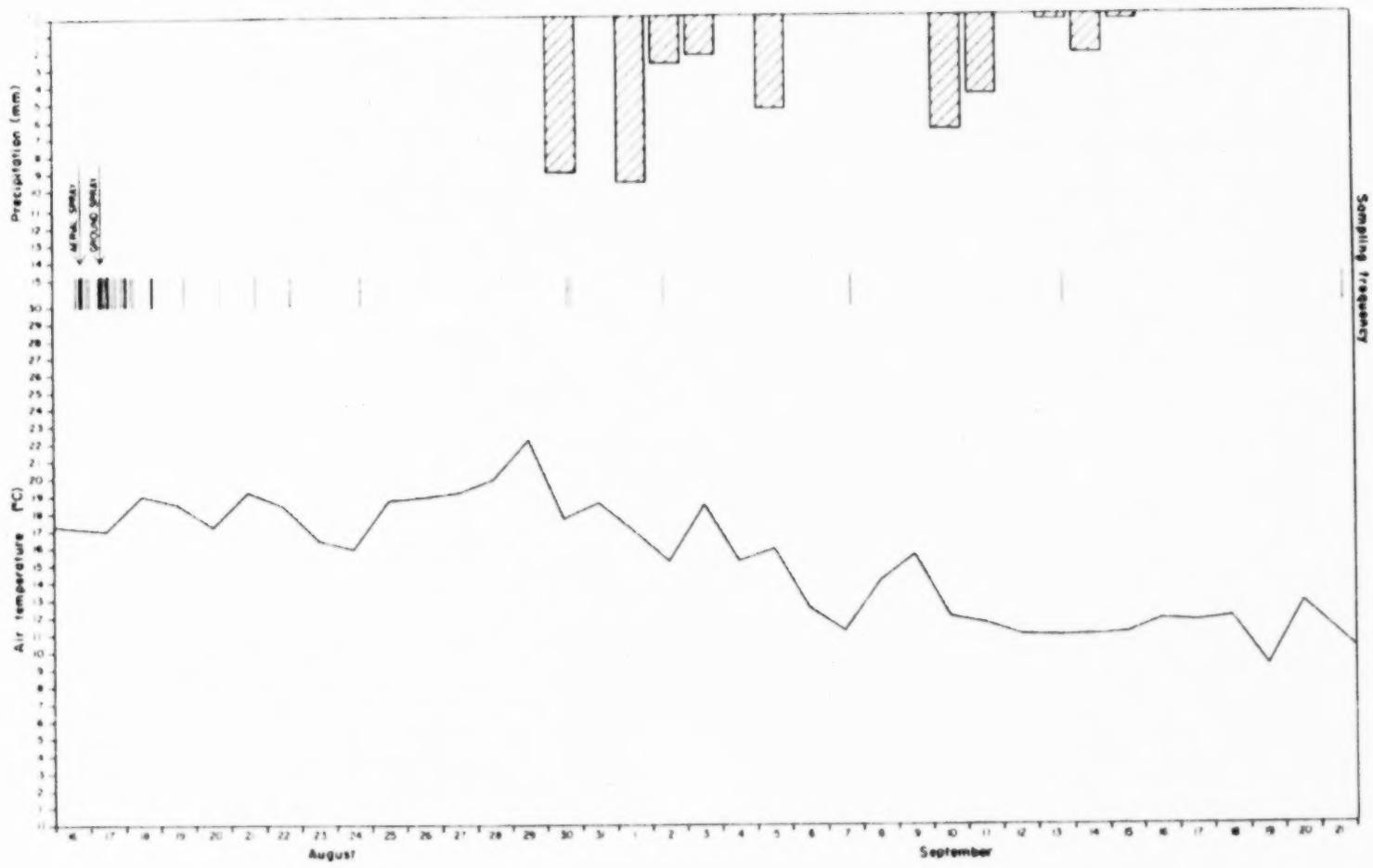

FIGURE 2. Climatic record for the period of water sampling. Frequency of sampling is indicated.

3 RESULTS

For all water samples, including those taken during the first rain event, there were no detectable levels of glyphosate or its major metabolite, AMPA, in the surface water during the study period (Table 2). A visual analysis of the Krome-Kote® cards within the buffer zone and the PFZ indicated that all cards intercepted spray droplets. The number and size of intercepted droplets varied with distance from the buffer, with the smallest and the fewest number occurring within the PFZ. Despite this observation, herbicide residues were not found in surface water immediately following the application. These results suggest that movement of glyphosate or AMPA residues to surface water from either aerial or ground sources was nominal for 36 days following application.

TABLE 2. Glyphosate and AMPA residues in surface water collected before, during, and following the application of Roundup®

Sample Date	Time (PST)	Time from spray above site (hr)	Residue concentration (mg/L)	
			Glyphosate	AMPA
16 August 1986	16:00	prespray	ND[a]	ND
	18:40	0.1	ND	ND
	19:10	0.5	ND	ND
	19:40	1	ND	ND
	20:40	1	ND	ND
	22:40	4	ND	ND
17 August 1986	00:40	6	ND	ND
	06:40	12	ND	ND
	09:30	15	ND	ND
	10:30	16	ND	ND
	12:40	18	ND	ND
	18:40	24 (1 day)	ND	ND
18 August 1986	06:40	36	ND	ND
	18:40	48 (2 days)	ND	ND
19 August 1986	18:55	72 (3 days)	ND	ND
20 August 1986	18:40	96 (4 days)	ND	ND
21 August 1986	18:40	120 (5 days)	ND	ND
22 August 1986	18:40	144 (6 days)	ND	ND
24 August 1986	18:40	192 (8 days)	ND	ND
30 August 1986	16:00	333.5	ND	ND
	18:40	336 (14 days)	ND	ND
02 September 1986	10:00	384 (16 days)	ND	ND
07 September 1986	18:40	528 (22 days)	ND	ND
13 September 1986	18:40	672 (28 days)	ND	ND
21 September 1986	18:40	864 (36 days)	ND	ND

[a] ND - not detected; detection limit = 0.005 mg/L for both glyphosate and AMPA (Environmental Laboratory, Ministry of Environment, Vancouver, B.C.).

4 DISCUSSION

The results of this study are consistent with what is known about the movement of Roundup® in forest conditions and its environmental fate as well as with what other researchers have found in monitoring glyphosate residues in surface water.

In British Columbia, Wan (1986) monitored glyphosate and AMPA concentrations in streams protected by buffer strips (60- to 100-m buffer, aerial application and 10-m buffer, ground application) and in an unprotected stream (no buffer, aerial application). In the unprotected stream, where application at 3.0 kg a.i./ha occurred directly on the stream surface, concentrations reached a peak of 0.023 mg/L, 2-3 hours following the spray. Glyphosate residues were further detected in the same stream following the first major rainstorm 8 days post-spray and peaked at 0.100 mg/L. Low levels (.006 mg/L) were also detected following the second rainstorm (14 days).

Streams that were buffered in Wan's study did not carry any detectable glyphosate residues immediately after treatment. On the area treated by aerial application, however, residues were detected at a later date following two rainstorms. Peak value was 0.025 mg/L. It was suggested that herbicide residues from vegetation along the streambank or in the treated area may have washed into the creek. No herbicide residues were detected in the water of the stream protected for backpack spray application in Wan's study.

In another British Columbia study, Eremko monitored glyphosate and AMPA residues following an aerial application of Roundup® at a rate of 2.14 kg a.i./ha.[2] The water courses were protected with a 100-m buffer on each side. Water samples were taken immediately following the application, daily for 1 week and weekly for 1 month. No detectable herbicide residues were found in any of the water samples in Eremko's study.

Newton *et al.* (1984) monitored glyphosate concentrations in streamwater after direct application at a rate of 3.3 kg a.i./ha to an open stream in Oregon. Streamwater was sampled on the downstream edge of the site at 5-minute intervals for 90 minutes, 10-minute intervals for the next 100 minutes, and 30 minutes for next 5.5 hours. Samples were also collected on days 1, 2, 3, 6, 7, 14, 28, and 55. Newton *et al.* found that they were able to detect concentration peaks of herbicide residues (less than 0.3 mg/L) as the helicopter made individual passes across the stream. Following initial application, glyphosate was not detected when leaching or surface runoff might carry notable levels of the herbicide. They attribute the absence of herbicide in runoff from the treated site to the adsorption of glyphosate to soil and organic debris.

In a study where glyphosate was applied to the banks of a canal at a rate of 5.6 kg a.i./ha approximately 23 weeks before water filled the canals, Comes *et al.* (1976) reported that water sampled within the treated area and immediately downstream from the treated area showed no detectable residues of glyphosate or AMPA during the first flows. They concluded that glyphosate can be applied to ditchbank vegetation with little or no chance of residue movement into the irrigation water the following spring.

Edwards *et al.* (1980) studied glyphosate residue movement in surface runoff from small agricultural watersheds (0.2-3.1 ha) in Ohio that were planted to corn and pasture crops. Pre-seeding treatments of Roundup® at rates of 1.10, 3.36 and 8.96 kg a.i./ha were made. At the lowest application rates, 1.10 and 3.36 kg a.i./ha, residues in surface water were detected up to 2 months following application. The highest concentration measured was 0.094 mg/L, which occurred during the first rain event 10 days after application. Where the herbicide was applied at the highest rate, 8.96 kg a.i./ha, a peak concentration of 5.153 mg/L was measured during the first rain event, which occurred 1 day after application. Concentrations of glyphosate were detected in runoff 4 months after treatment at this application rate. In this study, generated runoff was precipitation-dependent, with overland flow as the dominant pathway. Overland flow contributed to glyphosate movement, particularly when precipitation occurred within a few days after application.

The occurrence of glyphosate residues in surface runoff is attributed to direct application to the stream surface without buffer protection, to mobilization in ephemeral stream channels following rain events, or to overland flow. Leaching does not appear to be a pathway for glyphosate movement. When applied to the soil,

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[2] Eremko, R.D. 1986. The effects of the aerial application of Roundup® on water quality in the Nicoamen River watershed. Unpubl. report for B.C. Min. For. & Lands, Lillooet District.

glyphosate has been found to become inactive as a result of rapid adsorption to the soil (Sprankle *et al.* 1975 a,b; Hance 1976; Rueppel *et al.* 1977; Torstensson and Aamisepp 1977). Breakdown of glyphosate on the forest floor is linked to microbial activity. In litter covering the forest soil, Newton *et al.* (1984) reported a half life of 14 days, whereas on mineral soil they reported a half life of 40.2 days. The difference in breakdown was attributed to microbiological activity.

In this study, several minute droplets were observed on spray cards within the pesticide-free zone following the aerial application. However, herbicide residues were not found in the water samples. Dilution is one explanation of the nondetectability, although not the only one. Adsorption to suspended sediment and ultraviolet degradation may also occur. Comes *et al.* (1976) metered 150 ppb of glyphosate into canal water at one site and were able to account for about 70% of the chemical 1.6 km downstream. The data they presented showed that total quantity of glyphosate was reduced considerably downstream. They attributed the reduction to mechanisms of loss other than dilution. Where glyphosate was added to water containing soil particles, it has been noted that these particles can bind with glyphosate and effectively remove the residues from the water (Lund-Hoie and Friestad 1986). Glyphosate in water has also been shown to degrade under the presence of ultraviolet light (Lund-Hoie and Friestad 1986). In studies by Newton *et al.* (1984) and Wan (1986), concentrations of glyphosate residues were detected on stream bottom sediments. It appears that glyphosate residues disassociated in solution to bind to organic and mineral particle matter in the study streams. Due to the low volume of water in the seep monitored, and to its lack of sediment-carrying power, sediments were not sampled in this study.

5 CONCLUSIONS

Surface water draining from the cutblock treated with the herbicide Roundup® contained no measurable levels of glyphosate or AMPA residues. Both efficient operator performance and appropriate safeguards were critical to the successful control of the herbicide.

The results of this study and those of other published water quality studies suggest that prudent use of Roundup® adjacent to streams in forestry situations does not result in detectable levels (greater than 0.005 mg/L) of herbicide residues in surface water.

Regular operational monitoring of glyphosate in surface waters is not recommended. However, where contentious areas exist, a water quality monitoring program to check off-target movement provides a basis for evaluating the herbicide application. Where surface water drains through a treated area, deposited sediments should be sampled for herbicide residues as part of the monitoring program based on research done elsewhere. Regular use of Krome-Kote® drift cards would provide an immediate visual record of glyphosate deposition following the spray.

6 LITERATURE CITED

Baird, D. D., R. P. Upchurch, W. B. Homesley, and J. E. Franz. 1971. Introduction of a new broad spectrum postemergence herbicide class with utility for herbaceous perennial weed control. Proc. N. Cent. Weed Contr. Conf. 26:64-68.

Chykaliuk, P. B., J. R. Abernathy, and J. R. Gipson. 1981. Bibliography of glyphosate. MP-1443. Texas Agric. Exp. Stn., Texas A.&M. Univ., College Stn., Texas.

Comes, R. D., V. F. Burns, and A. D. Kelly. 1976. Residues and persistence of glyphosate in irrigation water. Weed Sci. 24:47-50.

Edwards, W. M., G. B. Triplett, Jr., and R. M. Kramer. 1980. A watershed study of glyphosate transport in runoff. J. Environ. Qual. 9:661-665.

Hance, R. J. 1976. Adsorption of glyphosate by soils. Pestic. Sci. 7:363-366.

Henigman, J. 1986. Pesticide use in B.C. forestry: 1986. *In* Proc. Symposium Vegetation Management. Assoc. of B.C. Professional Foresters/Southern Interior Silv. Committee, Kamloops, B.C., pp.169-174.

Lund-Hoie, K. and H. O. Friestad. 1986. Photodegradation of the herbicide glyphosate in water. Bull. Environ. Contam. Toxicol. 36:723-729.

Newton, M., K. M. Howard, B.R. Kelpsas, R. Danhaus, C. M. Lottman, and S.Dubelman. 1984. Fate of glyphosate in an Oregon forest ecosystem. J. Agric. Food Chem. 32:1144-1151.

Norris, L. A., H. W. Long, and S. V. Gregory. 1983. Influence of forest and rangeland management on anadromous fish habitat in western North America 9. Forest Chemicals. U.S. Dep. Agric. Gen. Tech. Report PNW-149.

Ponce, S. L. 1980. Water quality monitoring programs. W.S.D.G. Tech. Pap. WSDG-TP-00002. U.S. Dep. Agric. For. Serv., Fort Collins, Col.

Rueppel, M. L., B. B. Brightwell, J. Schaefer, and J. T. Marvel. 1977. Metabolism and degradation of glyphosate in soil and water. J. Agric. Food Chem. 25(3):517-528.

Sprankle, P., W. F. Meggitt, and D. Penner. 1975a. Rapid inactivation of glyphosate in the soil. Weed Sci. 23(3):224-228.

———. 1975b. Adsorption, mobility and microbial degradation of glyphosate in the soil. Weed Sci. 23(3):229-234.

Torstensson, N. T. L., and A. Aamisepp. 1977. Detoxification of glyphosate in soil. Weed Research 17:209-212.

U.S. Department of Agriculture Forest Service. 1984. Pesticide background statements. Vol. 1. Herbicides. Agric. Handb. No. 633. Washington, D.C.

Utzig, G. F., P. G. Comeau, D. L. Macdonald, M. V. Ketcheson, T. F. Braumandl, A. R. Warner, and G. W. Still. 1986. A field guide for identification and interpretation of ecosystems in the Nelson Forest Region. B.C. Min. For., Victoria, B.C.

Wan, M. T. K. 1986. The persistence of glyphosate and its metabolite amino- methyl-phosphonic acid in some coastal British Columbia streams. Regional Program Report 85-01. Dep. Environ., Environ. Prot. Serv., Vancouver, B.C.

Weed Science Society of America. 1979. Glyphosate. *In* Herbicide handbook. Weed Science Society of America, Champaigne, Ill., pp. 224-229.